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Final Report on AFOSR 96NL245

Near-Field Scanning Optical Microscope for Organic Photonic Materials

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1. Project Summary

In this project, we requested funds from the Air Force of Scientific Research (AFOSR) under DOD's Defense University Research Instrumentation Program (DURIP) to acquire a near-field scanning optical microscope (NSOM). Near-field scanning optical microscope (NSOM) is a unique research tool commercialized in the past two years, which provides unprecedented optical resolution defying the diffraction limit, as small as 1/20 laterally and 1/100 vertically. The funds from AFOSR has enabled us to purchase and install a state-of-the-art NSOM from TopoMetric. We have successfully installed and tested the instrument. A number of experiments have been performed using the instrument. The NSOM has proved to be a powerful instrument which allows innovative new approaches to address fundamental issues and enhance the existing and future DOD sponsored research projects in the University of Rochester. The preliminary application of the NSOM has already demonstrated the great potential of NSOM, its value to DOD sponsored research, and its usefulness for training future scientists and engineers for the DOD interests.

2. Acquisition and Installation

We have purchased from TopoMetric the AuroraTM NSOM whose ability of achieving true state-of-the-art performance has been well proven since its introduction in 1995. TopoMetric has licensed all the sixty plus SPM related patents from IBM, and has the exclusive right to the AT&T patents on NSOM. The NSOM has been installed and tested, and we have demonstrated the manufacturer specified optical resolution of ~50 nm. The University has provided funds of $5,000 to renovate the laboratory and purchase computer peripheral equipment for the NSOM. The University has also contributed a $10,000 optical table to support the NSOM, and the laser and other optical accessories. Xerox Corp. has donated a $50,000 Coherent I-20 Argon Laser to be used as the light source for the NSOM. To further enhance the capabilities of the NSOM, we have purchased a $12,000 Pipette Puller through other resources to prepare fiber optical tips for the NSOM, and have loaned a dye laser as a tunable light source.

3. Summary of the Cost

The total cost for the NSOM can be summarized in the following:

Source	Item	Cost	Status
AFOSR 96NL245	AuroraTM (NSOM)	$150,000	purchased
Xerox	Argon laser	$50,000	donated
U of R	Lab renovation and computer peripheral	$5,000	purchased
U of R	Optical table	$10,000	in use
Gao's group	Pipette puller	$12,000	purchased
Total cost		$227,000	

4. Enhancement to the Quality of Research Currently Funded by DOD

4.1. Interface and Lifetime of Organic Light Emitting Diodes (Gao)

A bottle neck for organic light emitting device (OLED) applications today is the device lifetime. It has been observed that the device degradation usually occurs at the organic/metal interface, starting as tiny dark spots which grow and overlap, leading to the decreasing efficiency and eventual destruction of the device. Clearly to understand the microscopic structural and chemical nature of these dark spots at the interface is an important step to overcome the lifetime problem, thus providing an efficient and robust device which could meet the increasingly critical specifications demanded by the display industry and the military in particular.

In our project "Interfaces in Organic Light Emitting Diodes" supported by DARPA DAAL 0196K0086, we address fundamental interface issues important for the future development of organic LED flat panel displays by applying surface/interface analytical techniques. However, the lack of a suitable tool for simultaneous optical and spectroscopic investigation at the interface may hinder our effort to apply the knowledge obtained through surface/interface analysis to the real devices.

The acquisition of NSOM gives us a powerful means to overcome this deficiency and substantially strengthen our DARPA project. As a first step, we have used the atomic force microscope (AFM) associated with the NSOM and investigated the mechanism of device degradation. We found that single Alq layer OLED devices have a decomposed organic layer at the ITO surface after operation, which explains the short device lifetime. This is the first direct evidence that device degradation by operation starts at the interface.

4.2. Phase Separation in Photonic Block Copolymers (Bazan)

Professor Bazan's work, supported by the Office of Naval Research, concerns with the phase separation process in conjugated polymers is important in determining their properties for photonic applications. Microdomain imaging is an integral but difficult part in our work supported by ONR. TEM techniques are usually relied upon to investigate phase separation. The major drawback here is the fact that the different components of a phase separated film need to be selectively stained. Toxic osmium tetroxide is used for this purpose but selectivity issues remain, i.e. which microdomain preferentially incorporates the staining agent. We have investigated using NSOM and AFM techniques to map out microdomain formation in block copolymers. The preliminary results indicate that the morphology is a sensitive function of the chemical composition.

5. Training of Future Scientists and Engineers

Mr. Francisco Avendano and Dr. Eric Forsythe, both in Prof. Gao's group, have done extensive test runs and fine tuning, and become highly proficient in operating the instrument. The NSOM has also been be made available to other students/scientists working on DOD and other projects to maximize its potential in the training of future scientists and engineers for the DOD interests.

LIST OF PUBLICATIONS FROM AFOSR 96NL245

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2. Quoc Toan Le, F. M. Avendano, E. W. Forsythe, Li Yan, C. W. Tang, and Yongli Gao, "X-Ray Photoelectron Spectroscopy and Atomic Force Microscopy Investigation of Stability Mechanism of Tris-(8-hydroxyquinoline) Aluminum Based Light-Emitting Diodes," J. Vac. Sci. Tech. A**17**, 2314 (1999).

3. E.W. Forsythe, M. Abkowitz, and Yongli Gao, "Tuning the Carrier Emission and Growth Modes," J. of Phys. Chem. B, **104**, 3948 (2000)

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5. E.W. Forsythe, M. Abkowitz, C.W. Tang, and Yongli Gao, "Growth Modes and Hole Injection Characteristics of Organic Films on Induim Tin Oxide Proceedings 10^{th} Annual Symposium of the NSF Center for Photoinduced Charge Transfer at University of Rochester, Rochester, NY July 25-28 World Scientific Publishing Co. (1999).